

Tides and Currents: Salinity and Tides

Author: NOAA

Grade Level: 9 - 12

Subject Area: Earth Science

SciGuide Resources: Resources
<http://www.vims.edu/cbnerr/>
http://tidesandcurrents.noaa.gov/ofs/cbofs/wl_nowcast.shtml
<http://web.vims.edu/physical/WEB/PRESNT/OTIME/Kimplot3.mov?svr=www>
<http://www3.vims.edu/vecos/StationDetail.aspx?param=YRK006.77&program=CMON>

Standards Addressed: **National Science Education Standards**
Content Standard A: Science as Inquiry
A3. Use technology and mathematics to improve investigations and communications.
A4. Formulate and revise scientific explanations using logic and evidence.
A6. Communicate and defend a scientific argument.
Content Standard B: Physical Science
B4. Motions and forces
B5. Conservation of energy and the increase in disorder
B6. Interactions of energy and matter
Content Standard D - Earth and Space Science
D1. Energy in the earth system
D2. Geochemical cycles

Time Required: Three 55-minute class periods plus homework

Lesson Goal: The students will be able to analyze data to describe daily patterns of salinity changes in the estuary.

Learning Objectives: Students will be able to:
1. Analyze different forms of data and synthesize information to develop a hypothesis.
2. Explain how tides and the geology of the estuary affect water circulation in an estuary.
3. Describe daily patterns of salinity changes in the estuary.

Prerequisite Knowledge: York River is one of several rivers flowing into Chesapeake Bay. As the nation's largest estuary, Chesapeake Bay contains a diverse collection of habitats including oyster reefs, seagrass beds, tidal wetlands, sandy shoals and mudflats. Chesapeake Bay and York River illustrate the complexities of tidal variation that respond not just to the gravitational pull of the Sun and the Moon, but also to the underlying topography of the bay and the dynamics of the estuarine river systems.
Chesapeake Bay Virginia National Estuarine Research Reserve has four sites on York River, enabling research and education about the estuary, including extensive data from water quality stations and other observations by reserve scientists. In this learning activity, students use this multi-site system to explore tides and salinity from tidal freshwater to high salinity conditions along York River estuary. Reserve components include Sweet Hall Marsh, Taskinas Creek, Catlett Island and Goodwin Islands Rivers. B

rivers discharge into Chesapeake Bay.

Procedures/Instructional
Strategy:

Procedure

Part 1 — Tides in Chesapeake Bay

Introduce students to the Chesapeake Bay. If need be, use a U.S. Map to show students the location of Chesapeake Bay. Students can also learn more about the bay using Google Earth (refer to the Student Reading — Using Google Earth to Explore Estuaries for a brief how-to guide) or they can read more about the Chesapeake Bay Virginia NERR website: <http://www.vims.edu/cbnerr/>

Using a computer projector for the whole class or letting students work individually or in teams in the computer lab, demonstrate the Tides in Chesapeake Bay website:

http://tidesandcurrents.noaa.gov/ofs/cbofs/wl_nowcast.shtml

Have students complete Part 1 of the Student Worksheet — Salinity and Tides.

Part 2 — Salinity as York River Flows into the Bay

Here, you focus on salinity, helping students think, in a general way, about the salinity gradient in the York River as the fresh water flows into the salty bay. Make sure the students understand the location of the York River in Chesapeake Bay. Have students complete Part 2 of the Student Worksheet — Salinity and Tides, labeling the York River map with “fresh,” “nearly fresh,” “fairly salty,” “close to seawater,” or “seawater.”

If students have hands-on experiences in mixing fresh and seawater and/or have measured samples of fresh, brackish, and seawater, they can label the map with their best guesses about salinity, which will range from 0 (fresh) to about 35 parts per thousand (ocean). Have students compare maps in small groups and explain why they marked them as they did. Discuss daily and seasonal factors and Earth processes that affect salinity in an estuary.

Have students read Student Reading — Estuarine Tides. (This can be assigned as homework.)

Part 3 — Interaction of Tides and River Flow

With this part, students deepen their understanding of estuarine systems, focusing on the interaction of tides and rivers and how this affects salinity in the estuary.

Using a computer projector for the whole class or letting students work individually or in teams in the computer lab, demonstrate the animation of tides and salinity in York River at this web site: www.vims.edu/physical/web/present/qtime/Kimplot3.mov

Make sure students are aware that the animation shows the change in salinity over a tidal cycle of 24 hours. Explain that the animation is not a representation of salinity changes for a specific date, but rather a model of what salinity distribution might be like in the river on any given day.

Provide a general orientation about the animation for students:

- The bottom and larger part of the animation shows horizontal distribution—salinity changing from upstream to downstream.
- There are four reference points on the animation. Three are sites for which students will analyze salinity.

graphs in Part 2. (GLPT is Gloucester Point, #1 is Yorktown, and #3 is Clay Bank.)

- The three images to the right show transverse slices of each of the three points—cut-away views of those locations—and show how saltier and fresher water is mixing from the surface of the water to the bottom.
- The scale on the left shows the amount of salinity in parts per thousand (ppt). Students should generally know that moving from blue to red on the scale represents fresh to increasingly saltier water.
- Students should also be aware that arrows on the image indicate the direction of water flow.
- The hour on the animation indicates the time of day on the 24-hour clock.
- The isohalines (lines on a chart connecting all points of equal salinity) help students determine levels of salinity.

Encourage students to play this animation several times, looking for general patterns first, then at specific phenomena and distribution at specific places.

Have students answer the first set of questions in Part 3 of the Student Worksheet — Salinity and Tides.

Have students look at the cross-section views in the upper right of the animation, showing salinity with depth in the river, at the lines marked 1, 2 & 3, and answer the remaining questions.

Part 4 — Salinity as Measured by Water Quality

Stations in York River

Having seen what a theoretical salinity distribution can look like in the river, students now observe actual salinity data for a specific day at five different sites along the river. You can do this activity either using computer access to near-current data or using the prepared data graphs in the Student Data Sheet — Salinity and Tide Data for York River.

If you use the computer access to data, follow the instructions in the Student Worksheet — Salinity and Tides. If you use the prepared graphs, hand them out to students.

Students will:

- Read information about the station including Salinity regime, Mean tidal range, Mean water depth, and Adjacent water.
- Make predictions about how fresher and saltier water will mix, and how salinity changes throughout the day will differ from site to site.
- Select data for the same date at each station. Students may select a date of their own choosing, but for the purposes of this initial activity, it will be best for the whole class to choose the same date for the sake of consistency when they are discussing results.
- Observe graphs of salinity data for that day at each site. It will be helpful for students to print out graphs for each site so they can compare changes from site to site, over time.

Encourage students to correlate the salinity graphs at the five sites with the generalized distribution shown in the animation. Students should pay particular attention to the graphs of Gloucester Point, Yorktown, and Clay Bank because this is the area marked by the three reference points in the animation.

Have students answer the questions in Part 4 of The Student Worksheet — Salinity and Tides.

1. Discuss the following:

- How do the changes at each monitoring station compare with changes at those same areas in the animation?
- Name several factors that determine why salinity changes are different depending on your location within the estuary.

2. Ask small groups to use their handouts to answer this question. Collect this assignment and use it as a final assessment. Imagine that an intense rainstorm dumps 3 inches of rain over the entire Chesapeake Bay region. Predict how the salinity would change at all four stations in the bay for a period of 24 hours after the storm ends. Supply a graph and an explanation of what you might expect to see at each station.

Outcome/Assessment: Students complete Student Worksheet – Salinity and Tides.

Extensions: Have students access other data from the VIMS site to see how factors such as precipitation and temperature might have affected salinity on that date.

Classroom Resources: Materials
Students

- Need to work in a computer lab or with a computer and projector
- Copy of the Student Reading - Estuarine Tides
- Copy of the Student Worksheet - Salinity and Tides
- Copy of the Student Data Sheet - Salinity and Tide Data for York River (if there is no computer access to the data)
- U.S. Map and/or Google Earth
- Copy of Student Reading - Using Google Earth to Explore Estuaries (assuming you have computer access) - Find the tutorial in estuaries.gov, click under Teachers,
- Classroom Activities and find the tutorial.
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Teachers bookmark these sites:

<http://www.vims.edu/cbnerr/>

http://tidesandcurrents.noaa.gov/ofs/cbofs/wl_nowcast.shtml

<http://web.vims.edu/physical/WEB/PRESNT/QTIME/Kimplot3.mov?svr=www>

<http://www3.vims.edu/vecos/StationDetail.aspx?param=YRK006.77&program=CMC>

Equipment:

Computer lab or Computer and Projector

Student Reading

Activity 2: Estuarine Tides

It's Not Just the Sun and Moon

What Affects Tides in Addition to the Sun and Moon?

The relative distances and positions of the sun, moon and Earth all affect the size and magnitude of the Earth's two tidal bulges. At a smaller scale, the magnitude of tides can be strongly influenced by the shape of the shoreline. When oceanic tidal bulges hit wide continental margins, the height of the tides can be magnified. Conversely, mid-oceanic islands not near continental margins typically experience very small tides of 1 meter or less. The shape of bays and estuaries also can magnify the intensity of tides. Funnel-shaped bays in particular can dramatically alter tidal magnitude. The Bay of Fundy in Nova Scotia is the classic example of this effect, and has the highest tides in the world—over 15 meters. Narrow inlets and shallow water also tend to dissipate incoming tides. Inland bays such as Laguna Madre, Texas, and Pamlico Sound, North Carolina, have areas classified as non-tidal even though they have ocean inlets. In estuaries with strong tidal rivers, such as the Delaware River and Columbia River, powerful seasonal river flows in the spring can severely alter or mask the incoming tide. Local wind and weather patterns also can affect tides. Strong offshore winds can move water away from coastlines, exaggerating low tide exposures. Onshore winds may act to pile up water onto the shoreline, virtually eliminating low tide exposures. High-pressure systems can depress sea levels, leading to clear sunny days with exceptionally low tides. Conversely, low-pressure systems that contribute to cloudy, rainy conditions typically are associated with tides that are much higher than predicted.

— Adapted from NOAA's National Ocean Service website, section on Tides & Water Levels.

URL: http://oceanservice.noaa.gov/education/kits/tides/tides08_othereffects.html.

Accessed: 2008-07-20. (Archived by WebCite® at <http://www.webcitation.org/5ZS2dFx8h>)



Student Worksheet

Activity 2: Salinity & Tides

Part 1 — Tides in Chesapeake Bay

You might think of tides as the simple rising and lowering of the sea level based on the gravitational pull of the sun and moon. However, tides are much more dynamic and interesting, especially in estuaries. In Chesapeake Bay, it can take several hours for the high tide to move from the mouth of the bay to the northern tip. The rivers feeding into the bay add their own dynamics to the tidal variations. Here, you will study animations of tides in the Chesapeake Bay and York Rivers to understand these tidal dynamics and their effect on salinity.

Tides in Chesapeake Bay

Go to the following web site, which has an animation that shows tides throughout the bay for the past 3 days: tidesandcurrents.noaa.gov/ofc/cbofs/wl_nowcast.shtml.

Watch the animation and look for patterns in the tidal pulse as it works its way up the bay. Notice the scale on the right, with yellows and reds as high tide, greens and blues as low tides. Step through the animation, pressing the “Prev” and “Next” buttons, to watch the tide move up the bay.

- 1a. At what time is the tide highest at the mouth of the bay near Norfolk? How high is the tide?
- 1b. At what time did this tidal rise reach the northern tip of the bay near Baltimore? How high is the tide?
- 1c. How long did it take the tide to move this distance?
- 1d. Which location has higher tides? Why?



- 1e. Which location do you think has saltier water?
Why?

Part 2 — Salinity as York River Flows into the Bay

Next, you take a closer look at York River to see how tides and the flowing river interact and affect salinity of the water.

The map below shows the York River where it empties into Chesapeake Bay. On the map, indicate how you think the salinity might differ throughout the river and into Chesapeake Bay. Label parts of the map “fresh,” “nearly fresh,” “fairly salty,” “close to seawater,” or “seawater.”



Figure 1.
The location of York River with respect to Chesapeake Bay

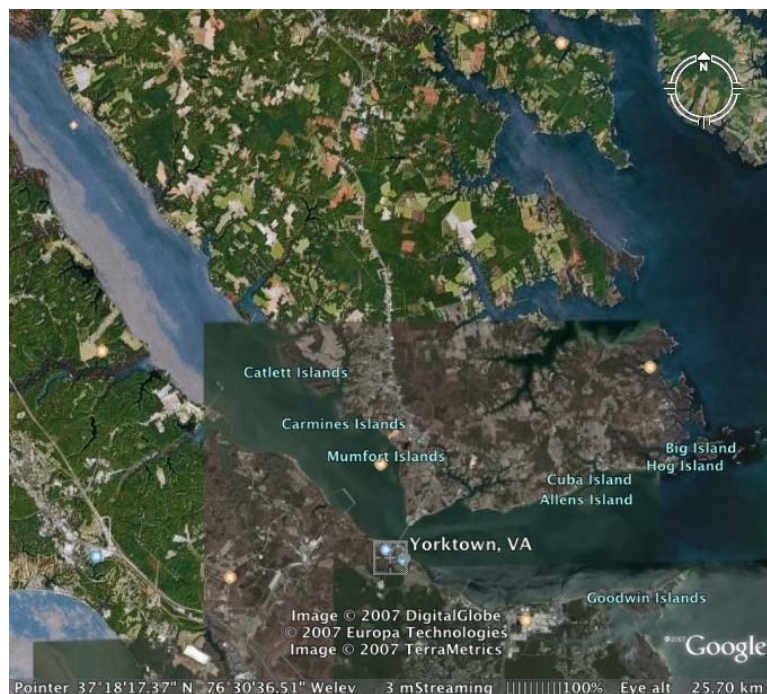


Figure 2.
Yorktown, Virginia is situated at the mouth of the York River.

Part 3 — Interaction of Tides and River Flow

Go to this web site: www.vims.edu/physical/web/present/qtime/Kimplot3.mov. The animation shows salinity in York River, and how it changes with the incoming and outgoing tide, over 24 hours.

Use the slide bar to control the animation at your own pace. Watch the animation several times, looking for patterns in the salinity. Notice the time counter at the top, marking half-hour increments, and the scale bar on the left showing salinity in parts-per-thousand (ppt).

- 3a. At the mouth of the river (lower right), what are the highest and lowest salinity levels, in ppt, during this time frame?
- 3b. Now look up river at the upper left of the animation. What are the highest and lowest salinity levels there?
- 3c. Why is there such a difference between these two locations?
- 3d. Play the animation and study the full extent of the river. How often do the arrows change direction? How does that affect salinity throughout the river?
- 3e. At what point are there greatest changes in salinity throughout the day? Why do you think so?
- 3f. Does the freshest water (the darkest blue) ever appear on the image? Where and for how long? Does the saltiest water (red) ever appear on the image? Where and for how long?



3g. Now look at the cross-section views in the upper right of the animation, showing salinity with depth in the river, at the lines marked 1, 2 & 3. How does the water get mixed from top to bottom as the salinity changes from upstream to downstream?

Part 4 — Salinity as Measured by Water Quality Stations in York River

The animations showed salinity distribution throughout a river based on a computer model. Now, you will observe actual salinity data for a specific day at five different sites along the York River. These sites use data buoys and other water quality stations to measure water depth, salinity, and other important data. These instruments support research at the Chesapeake Bay Virginia NERR and the affiliated Virginia Institute of Marine Science (VIMS).

You can do this activity in either of two ways: Use your computer to access real-time data and display your own graphs (see instructions below) or use the *Student Data Sheet* with its graphs for a sample date.

If you use your computer, follow these instructions:

- Open the Virginia Estuarine and Coastal Observing System site at: www2.vims.edu/vecos/SegmentChoice.aspx?param=MOBPH. This will bring up a page showing a regional view with some of the York River stations.
- Starting with Goodwin Island Continuous Monitoring Station (CHE019.38), click on each station, moving progressively up river (to Gloucester Point (YRK—5.40), Yorktown (YRK006.77), Clay Bank (YRK015.09), and Taskinas Creek (TSK000.23)).
- For each station, print the graphs of salinity and water depth.
- Read other information about the station including Salinity regime, Mean tidal range: 0.85 meters, and Mean water depth.



Figure 3. Location of selected monitoring stations in the Chesapeake Bay region.

Whether you use computer to access data or the pre-printed graphs, answer the following questions:

4a. Describe the general pattern of salinity data for each site:

Goodwin Island

Gloucester Point

Yorktown (this station is not included in the data sheets provided for March 21-22, 2007)

Clay Bank

Taskinas Creek.

4b. Describe changes in salinity from site to site.





Student Data Sheet

Activity 2: Salinity and Tide Data for York River

Salinity Data for March 21-22, 2007

Goodwin Islands Continuous Monitoring Station: CHE019.38

www2.vims.edu/vecos/StationDetail.aspx?param=CHE019.38&program=CMON

Location: N 37° 13' 01.2" W 76° 23' 19.2"

Tributary: York River

Salinity regime: Polyhaline

Mean tidal range: 0.79 meter

Mean water depth: 1.0 meter

Adjacent Water: located on the southern side of the York River, near the mouth of the River.

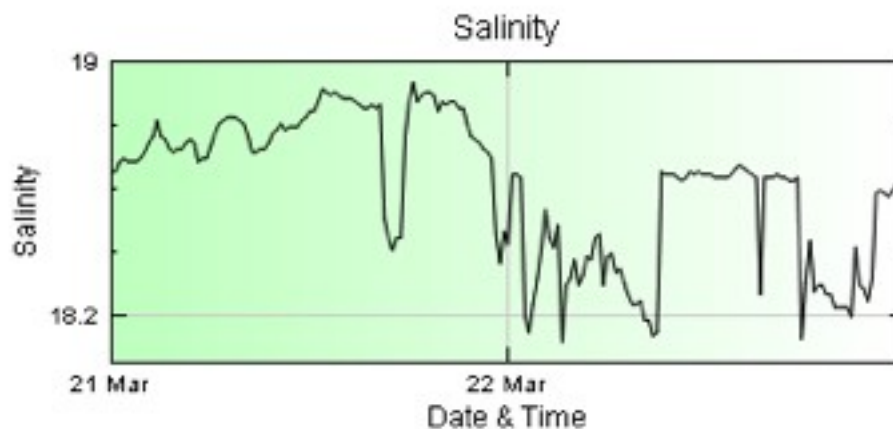


Figure 4. Salinity at Goodwin Islands Monitoring Station

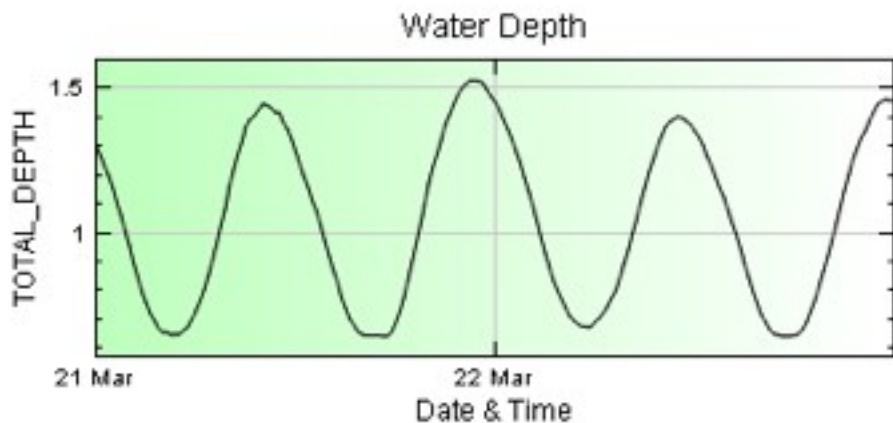


Figure 5. Water depth at Goodwin Islands Monitoring Station



Gloucester Point (GP) Continuous Monitoring Station: YRK005.40

Location: N 37° 14' 53.82" W 76° 29' 47.46" Tributary: York River

Salinity regime: Polyhaline

Mean tidal range: 0.73 meters

Mean water depth: 1.8 meters

Adjacent water: The Gloucester Point station is located north of the York River channel, approximately 5.4 nautical miles upstream from the River's mouth.

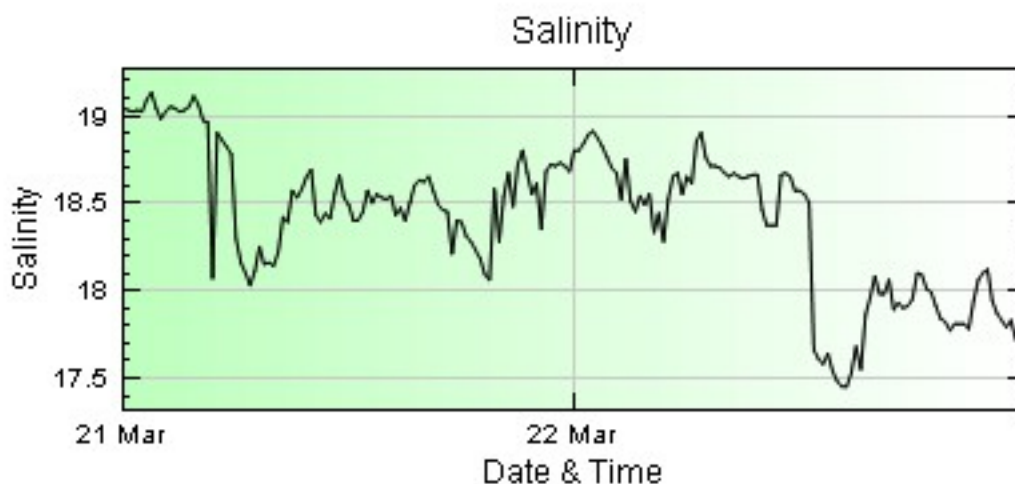


Figure 6. Salinity at Gloucester Point Monitoring Station

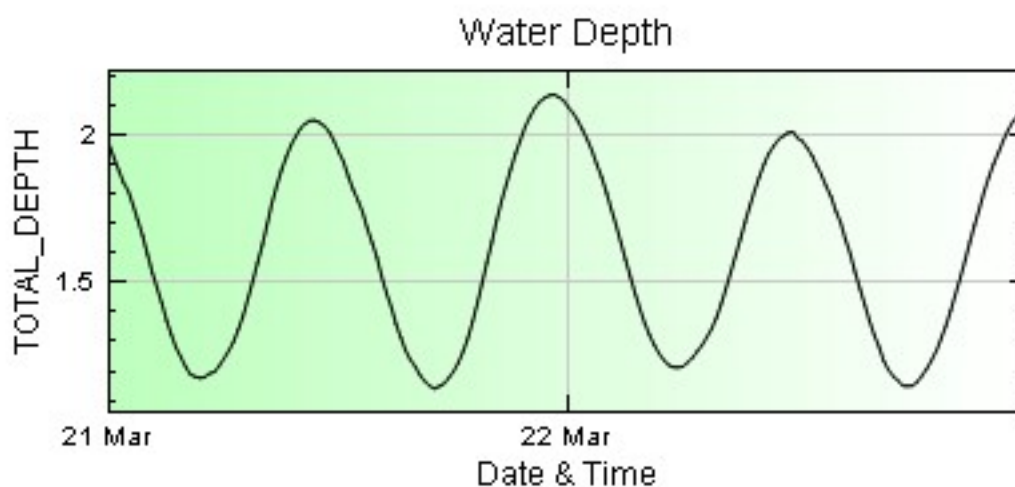


Figure 7. Water depth at Gloucester Point Monitoring Station

Claybank (CB) Continuous Monitoring Station: YRK015.09

Location: N 37° 20' 49.5" W76° 36' 41.94"

Tributary: York River

Salinity regime: Mesohaline

Mean tidal range: 0.85 meters

Mean water depth: 1.2 meters

Adjacent water: The Clay Bank station is located northeast of the York River channel, approximately 15.1 nautical miles upstream from the River's mouth.

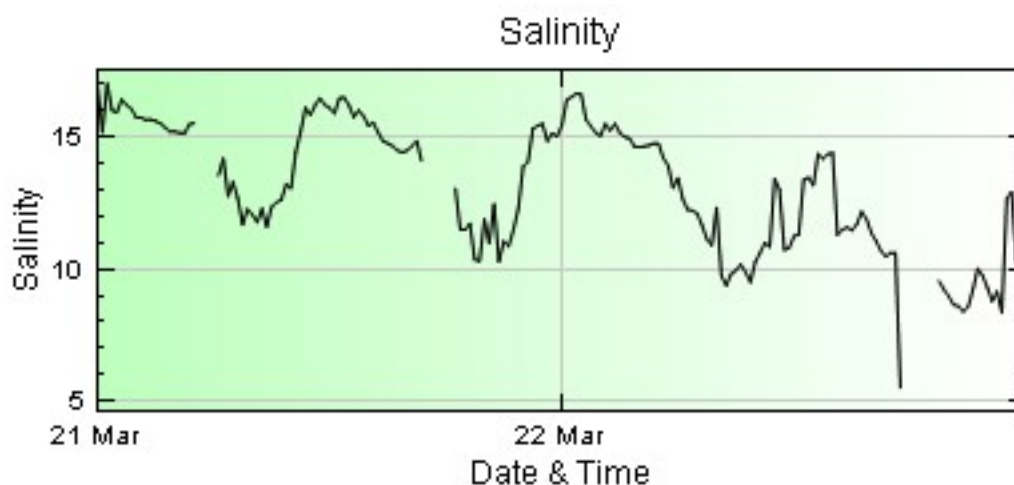


Figure 8. Salinity at Claybank Monitoring Station

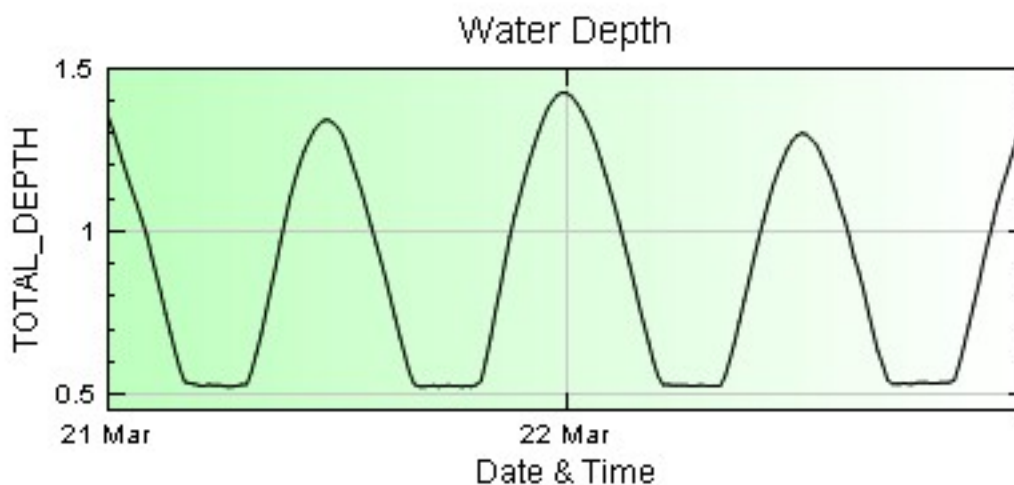


Figure 9. Water depth at Claybank Point Monitoring Station

Taskinas Creek (TC) Continuous Monitoring Station: TSK000.23

Location: N 37° 24' 54.79" W 76° 42' 52.74

Tributary: York River

Salinity regime: Mesohaline

Mean tidal range: 0.85 meters

Mean water depth: 1.5 meters

Adjacent water: The Taskinas Creek station is located southwest of the York River channel, approximately 23 miles upstream from the River's mouth.

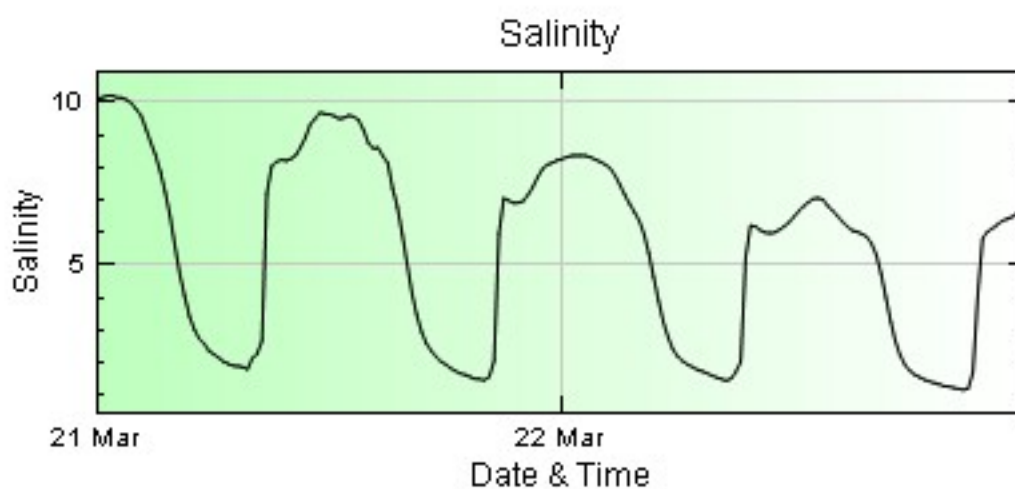


Figure 10. Salinity at Taskinas Creek Monitoring Station

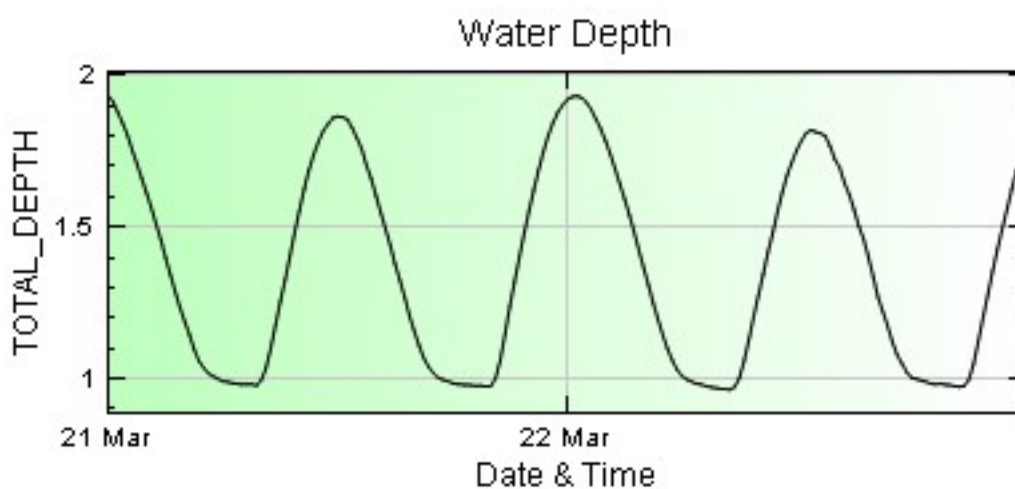


Figure 11. Water depth at Taskinas Creek Monitoring Station